

## UNIT 5: THE MUSCULAR SYSTEM

PLANNET UNIVERSITY SCHOOL  
ANATOMY AND PHYSIOLOGY

### AIDS TO UNDERSTANDING MUSCULAR ANATOMY

Calat - something inserted

Erg - work

Hyper - over, more

Inter - between

Laten - hidden

Myo - muscle

Sarco - flesh

Syn - together

Tetan - stiff

-troph - well fed



### 8.1 INTRODUCTION

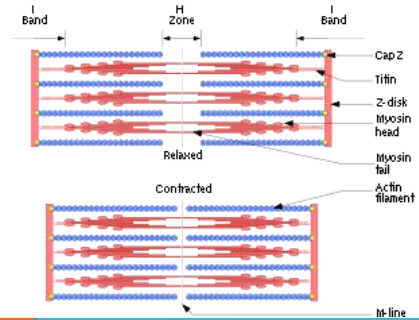
- All movements require muscle
- Muscles are organs comprised of specialized cells that use chemical energy to contract and flex
- Three Types of muscle:
  - Skeletal
  - Smooth
  - Cardiac
- Muscular actions:
  - Provide muscle tone
  - Propel body fluids and food
  - Generate a heartbeat
  - Distribute heat

### 8.2 STRUCTURE OF SKELETAL MUSCLE

- *Fascia* - layers of fibrous connective tissue separate individual skeletal muscle from one another
- Fascia surrounds the muscles and projects beyond its end to form a tendon
- Fibers in a tendon intertwine with those in the periosteum of the bone effectively attaching the muscle to the bone
- In some cases *aponeuroses* connect muscle to bone, not a tendon
- The layer of connective tissue that lies between the fascia and the muscle fibers is called *epimysium*, from there *perimysium* extends into the muscle to separate the muscle fibers into compartments
- The compartments formed by the perimysium are called *fascicles*
- Each fasciculi lies within a layer of connective tissue called *endomysium*

## SKELETAL MUSCLE FIBERS

- A skeletal muscle fiber is a single cell that contracts in response to a stimuli and relaxes at the conclusion of stimulus
- Each muscle fiber contains **sarcolemma** (cell membrane), **sarcoplasm** (cytoplasm), many oval nuclei, and mitochondria
- The sarcoplasm contains threadlike structures called *myofibrils* that lie parallel to one another
  - Two distinct structures of protein filaments form light and dark striations of skeletal muscle fiber
    - Myosin
      - Thick protein filaments
    - Actin
      - Thin protein filaments
    - Two other structures, troponin and tropomyosin, will be discussed later



### Know the Structures and Anatomy of the following

- I band – region between 2 myosin fibers
- Z Line – no fibers
- A Band – region of both actin and myosin
- H zone – only myosin
- M Line – a thickening band

Also, know that these structures make up a **sarcomere**



Within the sarcoplasm of muscle fibers is a network of membranous channels that surrounds each myofibril

- These membrane form the **sarcoplasmic reticulum**, the equivalent of endoplasmic reticulum in other cells
- Another set of membranous channels called **transverse tubules**, or **T Tubules** extend inward through the membrane to the outside, it contains extracellular fluid
  - Each T Tubule is located between two regions of sarcoplasmic reticulum which are enlarged and called **cisternae**, which are located where actin and myosin overlap
  - These two structures activate muscle contraction when the muscle fiber is stimulated



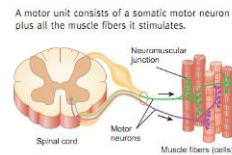
## NEUROMUSCULAR JUNCTION

- Each skeletal muscle fiber connects to an axon from a nerve cell called a *motor neuron*
- This axon extends outward from the brain or spinal cord and the muscle fiber contracts when impulses stimulate it
- The connection between the motor neuron and muscle fiber is called a *neuromuscular junction*
- At this site, the membrane of the muscle fiber is specialized to form a *motor end plate*. In this region, nuclei and mitochondria are prevalent and the membrane is extensively folded to increase contact with the axon of the motor neuron
- The motor neuron extends into the sarcoplasm and contains many tiny vesicles that store chemicals essential for neuron function, *neurotransmitters*



## MOTOR UNITS

- Each muscle fiber usually only has one motor end plate, but one neuron can attach to multiple muscle fibers due to its branched structure.
- When a signal is sent through the neuron, all fibers attached are stimulated simultaneously



## CHECK YOUR RECALL QUESTIONS

Complete the Check your recall questions on Page 175 and turn those in.



## SKELETAL MUSCLE CONTRACTION

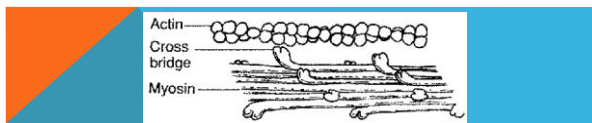
Skeletal Muscle Contraction is a very complex interaction of organelles and molecules

I will try my best to simplify this intensely complicated process...bear with me, and ask questions...



## THE ROLE OF MYOSIN AND ACTIN

- Myosin is composed of two twisted protein strands with globular parts called **cross bridges** that project outward, when grouped in large quantities these are called myosin fibers
- Actin is a globular structure with a binding site for myosin to attach, they are twisted into double helix and form an actin filament
  - The proteins troponin and tropomyosin are parts of the actin filament



## THE SLIDING FILAMENT MODEL

- Sarcomeres shorten because the cross bridges of myosin pull on the thin filaments of actin. When the cross bridges connect to actin, it bends slightly and pulls the actin fibers
- The globular portions of myosin house an enzyme called **ATPase** which catalyzes the lysis of ATP to ADP and phosphate and releases energy, this release of energy puts the myosin cross bridge into a "cocked" position. When it is cocked, it can attach to actin and pull to contract the muscle. After the cross bridge pulls, another ATP binding to the cross bridge causes it to be released from the actin before the ATP is split
- This action can theoretically continue as long as there is ATP available and muscles are being stimulated
- As the cross bridges pull, the actin filament moves towards the center of the sarcomere and as a result it shortens.



## WHAT STIMULATES CONTRACTION?

- A skeletal muscle normally does not contract unless a neurotransmitter stimulates it. In skeletal muscles, the neurotransmitter is **acetylcholine**.
  - Acetylcholine is synthesized in the cytoplasm of the motor neuron and stored in the vesicles that are in contact with the motor plate
  - When an impulse reaches the end of the motor neuron's axon, some of the vesicles release acetylcholine into the space between the axon and the motor plate
  - Acetylcholine diffuses quickly across the space (*synaptic cleft*) and combines with protein receptors in the membrane of the muscle fibers
  - This diffusion stimulates a muscle impulse which passes in all directions and stimulates the muscle to contract
    - The sarcoplasmic reticulum of the muscle fiber responds quickly to calcium concentration and releases it into the sarcoplasm
    - This results in troponin and tropomyosin being released and attachment to binding sites on actin causing linkage between the actin and myosin

Then, an enzyme, **acetylcholinesterase**, breaks down the initial flux of acetylcholine. This breaking down of acetylcholine prevents a single burst from continuously stimulating a muscle.

And that is how a contraction works...now for the process of relaxation...



## RELAXATION

- Once acetylcholine is broken down, calcium ions in the sarcoplasm are actively transported back into the sarcoplasmic reticulum
- The attachments between actin and myosin break and the muscle fiber relaxes
- See Table 8.1 for an itemized process of contraction and relaxation.



## ENERGY SOURCE FOR CONTRACTION

- **ATP** – the initial source of energy, it is short term, but regenerated by cellular processes
- **Creatine Phosphate** – the compound that makes ATP production possible
  - Contains very high energy phosphate bonds
  - When there is plenty of ATP, creatine phosphokinase catalyzes the synthesis of creatine phosphate
  - It stores excess energy in the mitochondria
  - Active muscle quickly uses up the supply of creatine phosphate, when it is exhausted, glucose is used to produce ATP



## OXYGEN SUPPLY AND CELLULAR RESPIRATION

- RBCs carry oxygen to hemoglobin molecules
- Muscle cells contain *myoglobin*, a pigment responsible for the reddish-brown color of muscle tissue
- Myoglobin can carry oxygen as well
- Thus, muscles can temporarily store oxygen
- When a person is resting or moderately active, the respiratory and circulatory systems can supply sufficient oxygen to support aerobic respiration.
- For anything more than a minute or two of physical activity, anaerobic respiration is the go to source of oxygen.



## OXYGEN DEBT

- In anaerobic respiration, glucose molecules break down into pyruvic acid which reacts to a low oxygen concentration to form lactic acid.
- Lactic acid is accumulated in the muscles and diffuses into the blood stream and reaches the liver
- As lactic acid accumulates, a person develops an **oxygen debt** that must be repaid
  - This is the amount of oxygen that liver cells are required to convert the lactic acid into glucose, plus the amount the muscles need to restore ATP and creatine phosphate
  - This is a very slow process and may take up to hours following physical activity
  - The more often muscular activity takes place, the muscles produce more capillaries and mitochondria and have a greater capacity for aerobic respiration



## MUSCLE FATIGUE AND HEAT PRODUCTION

- **Fatigue**
  - The loss of a muscle's ability to contract
  - Usually occurs from a surplus of lactic acid
  - A cramp can occur
    - A cramp is when a muscle undergoes continuous involuntary contraction.
    - Cramps occur as a result of chemical imbalance in the muscle fibers
- **Heat Production**
  - Over half of the energy used in cellular respiration is given off as heat
  - Because of muscle being such a huge component of body mass, it release more heat than any other organ system
  - Blood transports heat to and from muscles regulating temperature



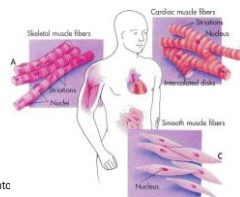
## MUSCULAR RESPONSES

- **Threshold Stimulus** – the minimum strength required to cause a contraction
- **All-or-None Response** – a muscle will respond with all of its might or none at all if it exposed to the threshold. The strength of the stimulus has no effect on the amount of response from the muscle
- **Recording a Muscle Contraction**
  - Myogram – the recorded electronic impulse and movement of a muscle graphically displayed
    - Twitch – a single contraction that only lasts a fraction of a second, appears as a spike on a myogram (figure 8.12)
    - Latent Period – the amount of time from the initial application of the stimulus to the time the muscle responds
    - Summation – When multiple stimuli hit a muscle and it does not have time to fully recover before the next stimulus hits it (Figure 8.13 B)
    - Tetanic contraction – when the muscle does not make any effort to relax following a series of impulses, the muscle can not relax due to exhaustion or chemical affect (Figure 8.13 C)
    - Recruitment – when multiple motor neurons are activated in response to stimuli
    - Muscle tone – the minimal amount of contraction that occurs even at a resting state



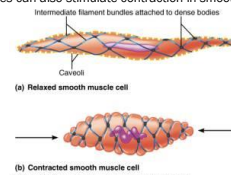
## 8.5 SMOOTH MUSCLE

- **Smooth, elongated cells with tapering ends**
- **Contain filaments of actin and myosin**
- **Organized more randomly than skeletal muscle**
- **No Striations**
- **Two major types of smooth muscle:**
  - **Multiunit Smooth Muscle**
    - Muscle fibers are separate rather than organized into
    - Found in the iris of the eye and blood vessels
    - Typically only contracts in response to motor nerves or hormones
  - **Visceral Smooth Muscle**
    - Sheets of spindle shaped cells
    - Found in the walls of hollow organs such as the stomach, intestines, bladder and uterus
    - Can stimulate one another
    - **Rhythmicity** – a pattern of repeated contractions
    - **Peristalsis** – a wavelike motion that occurs in tubular organs like the intestines and esophagus



## SMOOTH MUSCLE CONTRACTION

- **Similar to skeletal muscle except:**
  - Two neurotransmitters are used (acetylcholine and norepinephrine)
  - They both stimulate and inhibit certain parts of the process
  - Some hormones can also stimulate contraction in smooth muscle



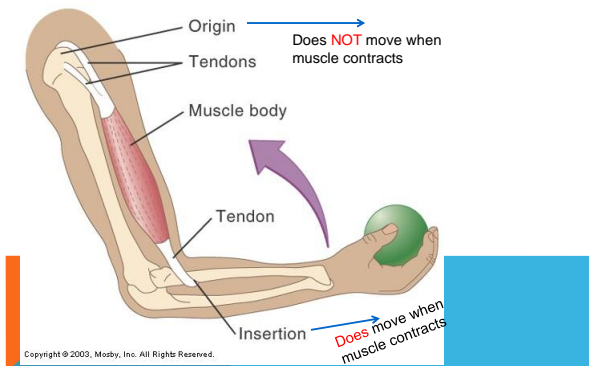
## 8.6 CARDIAC MUSCLE

- Found only in the heart
- Striated cells joined end to end. The fibers form 3D branching networks
- Transverse tubules release large amounts of calcium into the sarcoplasm and causes the cardiac muscle to twitch
  - Cardiac twitch lasts longer than skeletal muscle twitch
- **Intercalated discs** - connect muscle fibers by cross-bands
  - Transmit the force of contraction from cell to cell
- Cardiac muscle is self-stimulating and rhythmic

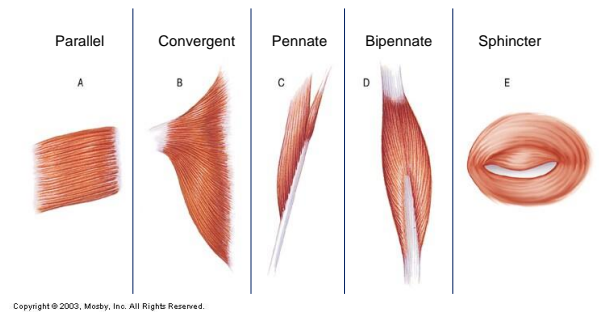
## MUSCLE TYPES SUMMARY

	SMOOTH	CARDIAC	SKELETAL
Location	Wall of hollow organs, vessels, respiratory passageways	Wall of heart	Attached to bones
Cell characteristics	Tapered at each end, branching networks, nonstriated	Branching networks; special membranes (intercalated disks) between cells; single nucleus; lightly striated	Long and cylindrical; multinucleated; heavily striated
Control	Involuntary	Involuntary	Voluntary
Action	Produces peristalsis; contracts and relaxes slowly; may sustain contraction	Pumps blood out of heart; self-excitatory but influenced by nervous system and hormones	Produces movement at joints; stimulated by nervous system; contracts and relaxes rapidly

## MUSCLE ATTACHMENT



## MUSCLE FIBER ARRANGEMENT



## NAMING MUSCLES

**Location**  
**Function**  
**Shape**  
**Fiber direction**  
**Number of heads/divisions**  
**Points of attachment**  
**Muscle size**



## Location

Frontalis	Frontal bone
Femoris	Femur
Gluteus	Posterior of hip/thigh
Oculi	Eye
Oris	Mouth
Radialis	Radius
Ulnaris	Ulna
Brachialis	Arm

## Function

Abductor	Moves part away from body
Adductor	Moves part toward body
Depressor	Lowers a part
Extensor	Extends a part
Flexor	Flexes a part
Levator	Elevates a part
Rotator	Rotates a part

## Shape

Deltoid	Shaped like delta Δ
Orbicularis	Circular
Platy	Flattened; platelike
Quadratus	Square
Rhomboides	Diamond-shaped
Trapezius	Trapezoidal

## Fiber Direction

Oblique	Diagonal to midline
Rectus	Parallel to midline
Sphincter	Circling an opening
Transversus	Right angle to midline

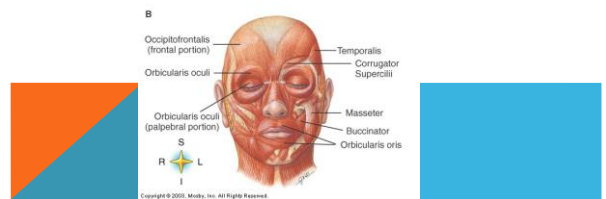
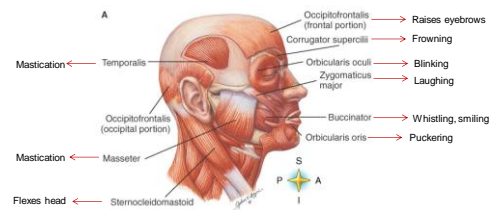
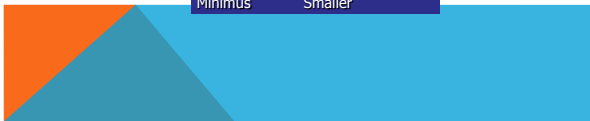


## Number of divisions

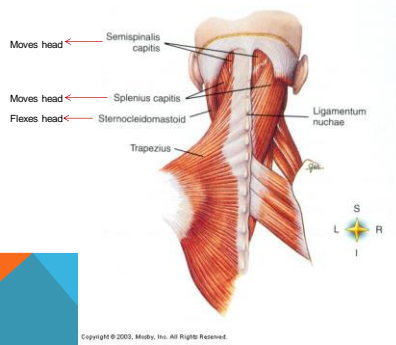
Bicep	Two heads
Tricep	Three heads
Quadricep	Four heads

## Size

Brevis	Short
Longus	Long
Magnus	Large
Maximus	Largest
Medius	Moderately sized
Minimus	Smaller

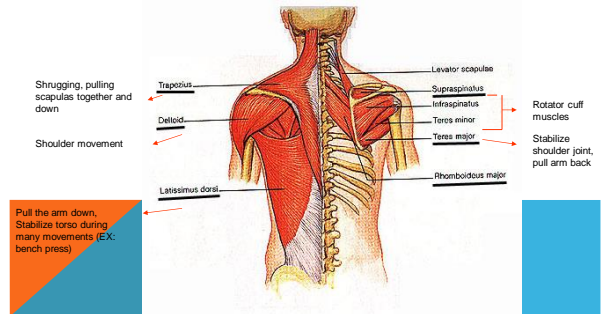




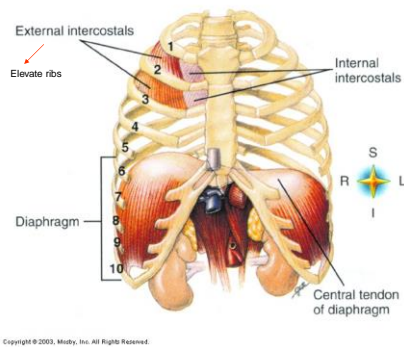


## SUPERFICIAL BACK MUSCLES

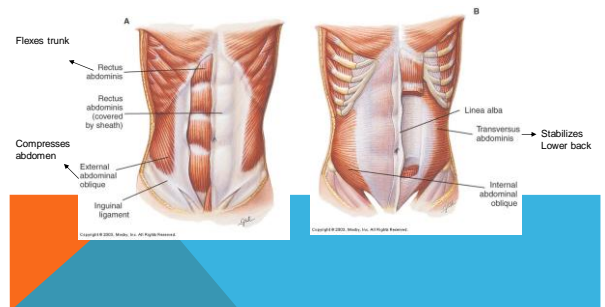
- Large, fan-shaped muscles provide force in a wide range of body positions
- EX: leaning back to straight vertical and all points in between.



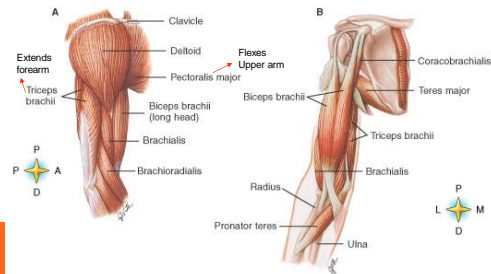
## TRUNK MUSCLES - THORAX



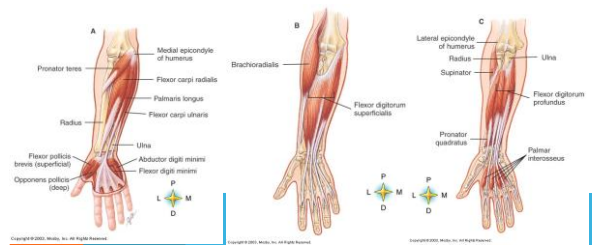
## TRUNK MUSCLES ABDOMEN



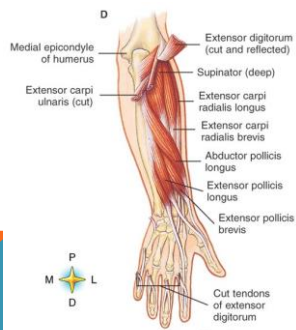
## UPPER ARM



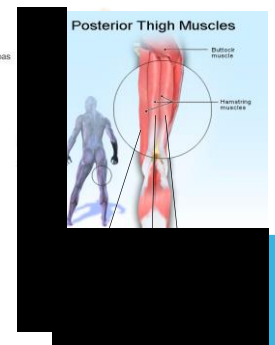
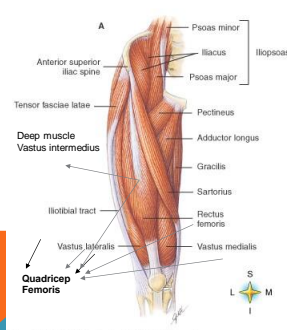
## FLEXORS



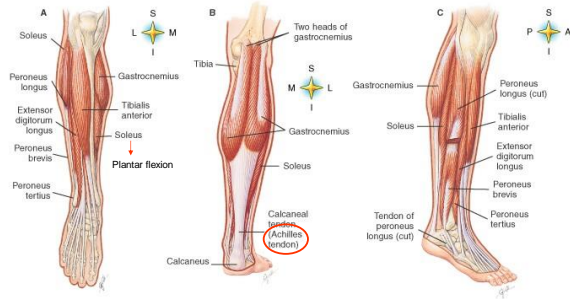
## EXTENSORS



## UPPER LEG

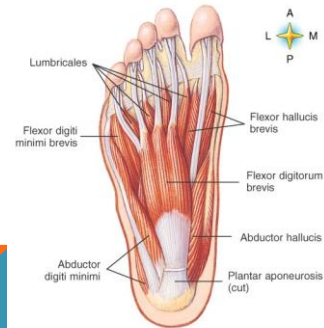


## Lower Leg



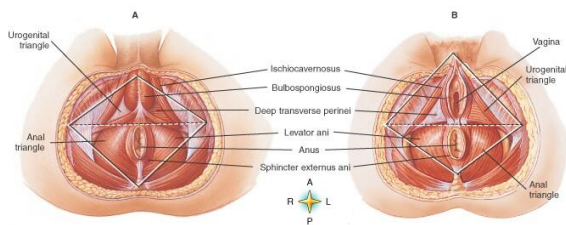
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## Foot



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## ANAL AND UROGENITAL MUSCLES



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## POSTURE

**Good Posture** – body alignment that favors function with least work

- Standing Position
  - Head and chest held high
  - Chin, abdomen, buttocks pulled in
  - Knees slightly bent
  - Feet firmly on ground 6 in. apart

**Poor Posture** – puts abnormal strain on ligaments and bones

### Maintenance

- Tonicity (muscle tone): muscles exert a pull against gravity
  - Continuous and passive partial contraction of muscles

## CLASSIFICATION OF MUSCLE GROUP ACTIONS

### Agonist (Prime Mover)

- Muscle most responsible for movement

### Antagonist

- Opposes prime mover
- Provides precision and control during prime mover contraction
- Relaxes when prime mover contracts

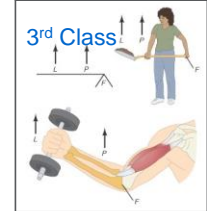
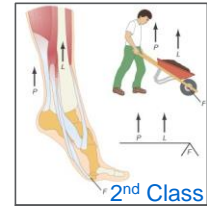
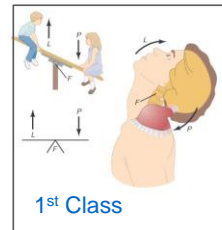
### Synergist

- Aid prime mover
- Contract at same time as prime mover

### Fixator

- Joint stabilizer
- Maintains posture/balance during prime mover contraction

## LEVER SYSTEMS



P = Force (push or pull)  
 Contracting Muscle  
 F = Fulcrum  
 Joint  
 L = Load  
 Weights, etc

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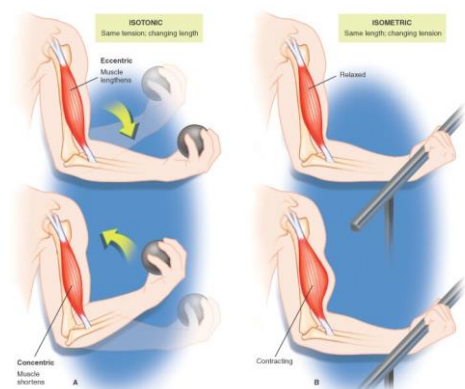
## MUSCLES & AGE

### Infancy & Childhood

- Muscle coordination and control allows developmental sequences to occur

### Aging

- Muscles degenerate with age
- Replaced with CT



Most body movements are a result of both types

## CHANGE IN MUSCLE SIZE

### Atrophy - decrease in muscle size

- Bed Rest: lose 1% muscle strength/day

### Hypertrophy - Increase in muscle size

## MYOPATHIES

**Myalgia** - muscle pain due to overstretching/tearing of muscle fibers

**Fibromyalgia** - widespread muscle and CT pain

**Strain** - caused by overexertion/trauma and can lead to muscle tear

**Myositis** - any muscle inflammation

**Fibromyositis** - tendon inflammation along with myositis

### Cramps

- Painful muscle spasms
- Due to mild myositis, fibromyositis, irritation, iron, and water imbalance
- Charley Horse
  - Intense muscle spasms
  - Last few seconds to few hours
  - Caused by injury or overuse
    - Dehydration
    - Low K<sup>+</sup> or Ca<sup>2+</sup>
    - Nerve irritated
- Treatment
  - Stop activity
  - Stretch and massage
  - Heat to relax muscle
  - Ice when spasm is over



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## MYOPATHIES

### Contusion

- Muscle bruise, local internal bleeding and inflammation
- Crush injury; severe trauma to muscle, releasing fibers into bloodstream (life threatening)

### Poliomyelitis (Polio)

- Viral infection of nerves controlling skeletal movement
- Causes partial or full paralysis and death
- Vaccine created in US in 1950s, but not everywhere

### Muscular Dystrophy

- Genetic disease caused by muscle atrophy
- Some forms are fatal
- Most common form is Duchenne Muscular Dystrophy (DMD)

### Myasthenia Gravis

- Autoimmune disease that attacks muscle cells at NM junction
- Muscle weakness
- Can become a crisis and affect all four limbs
- Could die of respiratory failure

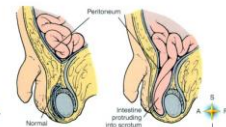
## MYOPATHIES

### Hernias

- "protrusion"
- Reducible - can manipulate protruding organ back into abdominal cavity
- Strangulated - blood flow to organ is stopped; obstruction, gangrene, pain. Vomiting, emergency surgery
- Types
  - Inguinal - hernia extends into inguinal canal into scrotum or labia; affects more males
  - Femoral - affects more women below groin area due to pregnancy



Inguinal hernia.



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